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The ANDROID case study; Venice and its territory: existing mitigation options and challenges for the future

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Abstract

The Work Package 7 (Research Futures & Special Interest Groups) of the ANDROID project, within a specific working group, selected Venice and its territory as an emblematic case study of a region that could be affected by cross-border disastrous events. The paper provides a general overview on the topic, trying to organise the large amount of available scientific literature in some strategic cores, identifying undoubted milestones, open questions and future research needs, following a holistic approach to risk assessment. This case study is carried out not only as an engaging exercise, but with the purpose to provide a reference point for scientists and teachers interested to translate multifaceted knowledge into specific solutions. In fact, the paper is strongly linked as a whole to other three ones (presented at the 4th International Conference on Building resilience by WP7 group participants), which deepen respectively hazard, vulnerability/resilience, and mitigation about the site taken into consideration. Furthermore, the City of Venice takes part to the UNISDR Program "Making Cities Resilient", and planned a robust intervention, consisting in the realisation of mobile dikes located at the openings of the lagoon (MOSE project, almost terminated), which has been strongly debated since the beginning, due to possible negative consequences on the environment. At last, the paper analyses drawbacks and benefits of the above said intervention, and suggests further proposals for the global safeguard of Venice and its lagoon.

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Keywords: Venice, risk assessment, natural and anthropogenic hazards, safeguard and mitigation

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1. Introduction

ANDROID is an Erasmus academic network that aims to promote co-operation and innovation among European Higher Education to increase society's resilience to disasters of human and natural origin. In the framework of the ANDROID Working Package 7, The Venice case study has been selected for the following main reasons: it could be affected by cross-border disastrous events; at least three European countries could be involved (Italy, Slovenia, Croatia); the territory is potentially interested by a multi-hazard scenario; the target is really complex (population, heritage, environment, industrial facilities, tourism, etc.), including the lagoon, the islands and the mainland. Furthermore, it is the place where a mobile tidal barrier system is going to be concluded soon.

This paper evaluates the existing and proposed mitigation options that are carried out to reduce the multi-hazard vulnerability of the Venice lagoon and the surrounding area. It carries out a review to establish the objectives, responsibilities, instruments and measures that were employed for carrying out these safeguarding activities. The paper examines the impact of the mobile tidal barrier system (MOSE, started in 1987 and to be completed in 2014), coastal reinforcement measures, the raising of quaysides, inner canal dredging and the paving and other infrastructure improvements to mitigate the impact from flooding which are designed to protect Venice and the lagoon. The impact of early forecasting and warning systems, improved communications to all stakeholders and service providers to improve rapid responses is also discussed.

Fig. 1. The Venice lagoon in the 15th century (left) and today (right).

In the 15th century, the lagoon of Venice was very different from today (Fig. 1 left side). For over five centuries, the continuous human intervention has allowed Venice lagoon to be preserved along with the ''lagoon status'' of the environment around it: important structural engineering works, starting in the 16th century, after a long and passionate debate both from scientific and political aspects, were aimed at diverting most of the rivers from the lagoon to the sea and so maintained the "water wall'' around the city, essential for defence reasons and Venice's strategic economic role as a city-port. The last big and very expensive public work undertaken by the Venetian Republic was the building of the seacoast defences (so call "Murazzi") at the end of the 18th century, completed only two years before surrendering to Napoleon's Army. More recently, the long jetties built between the late 19th and early 20th centuries determined the present form of the Lido, Malamocco and Chioggia inlets. To facilitate Venice's economic development, a large industrial area in Marghera was created at the beginning of the 20th century (around the year1910), and deep canals were also dug through the lagoon to connect the new port to the inlets, as well as the creation of artificial islands for further industrial growth. Fish farms have also been introduced in the northern and southern parts of the lagoon. A few decades ago, the airport was built on reclaimed land on the lagoon's margin. Nowadays, the extensive and comprehensive monitoring programme of the lagoon is making use of diverse techniques, from satellites to hundreds of physical–chemical and biological sampling campaigns and measurement networks. The Municipality of Venice is managing one of the biggest and delicate urban maintenance programmes in the world and runs a sea-level forecast and flood alert system based on direct measurements and sophisticated models (Campostrini 2004).

2. State-of-the-art about the existing mitigation options

2.1. Main local Institutions involved

The principal institution devoted to the research activities on the Venice lagoon is *CORILA* (namely "COnsorzio per il coordinamento delle RIcerche inerenti il sistema LAgunare di Venezia" - Consortium for coordination of research activities concerning the Venice lagoon system, http://www.corila.it/), a non-profit organisation overseen by the Ministry of Education, University and Research. *CORILA* promotes and coordinates research also internationally, facilitating interaction with the international scientific community; collects information on the physical system, territorial, environmental, economic and social aspects of the lagoon and lagoon settlements; processes and manages this information in an integrated framework; carries out interdisciplinary scientific research projects relevant to the problems of the Venice Lagoon; and organises widespread research dissemination. The Venice Ca' Foscari University, the IUAV University of Venice, the University of Padua, the Marine science institute of the Italy's National Research Council (CNR-ISMAR), located in Venice; the Italy's National Institute of Oceanography and Experimental Geophysics (OGS), located in the vicinity of Trieste; the Venice Water Authority (specific to Venice and belonging to the Italian Ministry of Infrastructure and Transportation) are associated in *CORILA*.

The Venice Municipality (http://www.comune.venezia.it/) manages the Centre for Sea-level Forecast/Flood Alert, together with the Local Civil Protection Office (which updated the Civil Protection Plan in 2009).

Other observatories monitoring soil, water, air, landscape, mobility, urban planning, cartography, commerce, and tourism belong to the Regione Veneto (http://www.regione.veneto.it/), with particular reference to ARPAV (Veneto Regional Agency for the environmental prevention and protection, www.arpa.veneto.it/).

2.2. Some reference studies and projects on Venice and its lagoon

In the last decades, a large number of technical-scientific materials and publications have been produced in the framework of many conferences, seminars and workshops by official institutions, independent organisations, and individual researchers about Venice and its lagoon. The fields of research interest were mainly devoted to environment physical description and quality, relationship with global warming scenarios, hazards (with particular emphasis on flooding; mathematical modelling and engineering solutions), urban system and planning, infrastructure, heritage, economy and tourism, protection, conservation and restoration measures, alert and forecasting, issues, approaches and research needs; examples are reported within the manuscripts of Ramieri (2000); Fletcher and Spencer (2005); Schibel and Guerrieri (2006); Prasad et al. (2009); Crooks et al. (2011); UNISDR (2012). Selected examples of key sectorial adaptation opportunities pertaining to urban areas are shown by Table 1.

Table 1. Selected examples of key sectorial adaptation opportunities pertaining to urban areas (source: IPCC 2007).

sector	*adaptation option/strategy*	*underlying policy framework*	*key (-) constraints and (+) opportunities to implementation*
water (e.g. King Country/Seattle, Singapore)	expanded rainwater harvesting; water storage and conservation techniques; water reuse; desalination; water use and irrigation efficiency.	national water policies and integrated water resources management; water-related hazards management.	(-) financial, human resources, and physical barriers; (+) integrated water resources management; synergies with other sectors.
infrastructure and settlements (including coastal zones) (e.g. Venice, London, New York)	relocation; seawalls and stormsurge barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea-level rise and flooding; protection of existing natural barriers.	standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance.	(-) financial and technological barriers; (+) availability of relocation space; integrated policies and management; synergies with sustainable development goals.

Furthermore, several EU projects (ADRI-PLAN "*Adriatic Ionian Maritime Spatial Planning*", MARE 2012-2025; Kulturisk, "*Knowledge-based approach to develop a culture of Risk prevention*", FP7 Environment 2011-2013; APICE, "*Identification of the risk activities and vulnerability systems in terms of present and future emissions in the Port of Venice*", MED 2007-2013; THESEUS, "*Innovative technologies for safer European coasts in a changing climate*", FP7 Environment 2009-2013; Ourcoast, "*Exchange of experience and comparative analysis for Integrated Coastal Zone Management*", DG Environment 2009-2011; GIS4EU, "*Provision of interoperable datasets to open GI to EU communities*", Programme eContentplus 2009-2010; SUFALNET, "*Sustainable Use of Former and Abandoned Landfills Network*", INTERREG IIIC 2005-2007; NASCUM, "*North Adriatic Surface Current Mapping*", INTERREG IIIA 2007-2008; ENCORA, "*European platform for sharing knowledge and experience in coastal science, policy and practice*" FP6 SUSTDEV 2006-2009; CoWaMa, "*Coastal Water Management*", INTERREG IIIA 2007-2008; SPICOSA, "*Science and Policy Integration for Coastal System Assessment*", FP6 SUSTDEV 2007-2011), other International, and Italian projects involved Venice institutions on research and cooperation programmes.

2.3. Mitigation measures adopted : the MOSE project

A mobile tidal barrier system (MOSE, "*MOdulo Sperimentale Elettromeccanico" - Experimental Electromechanical Module*) is the most relevant measure to defend the Venice from floods (Fig. 2). It involves the construction of 79 gates at the 3 lagoon inlets. Each gate will be up to 92 feet long, 65 feet wide, and will weigh 300 tons. When waters rise 1.1 meters (43 inches) above the normal level, air will be injected into the hollow gates, causing them to rise, blocking seawater from entering the lagoon, and thereby preventing the flooding of Venice. In the opinion of the designers, when the doors are at rest, they will be lying on the bottom of the inlet channel; depending on the type of tides, it is possible to manage the gates in a flexible way: only one inlet closed, no need to close the whole lagoon depending on sea tides, wind, and rain, maintaining in fact a continuous exchange of water from the open sea to the lagoon. The research related to MOSE building up at different scale/dimension of interests (i.e. impacts evaluation, alternative solutions examination, social discussion, scientific studies and experimental programs, institutional documents) are reported in a specific web page of the Venice Municipality (http://www2.comune.venezia.it/mose-doc-prg/, in Italian).

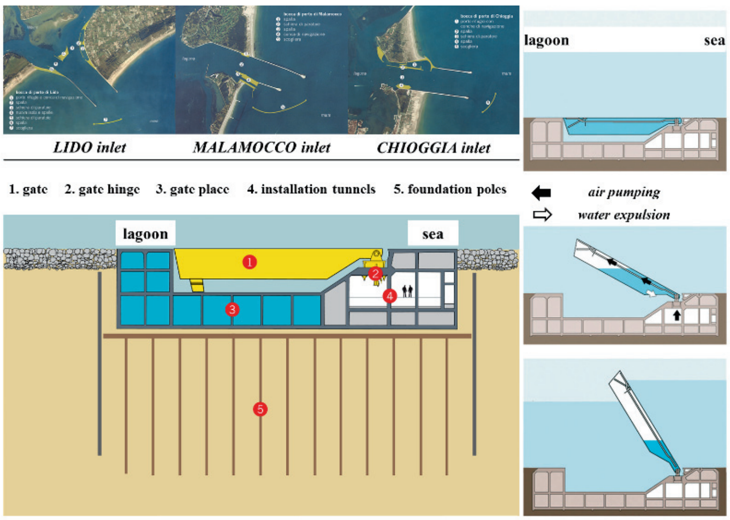

Fig. 2. The MOSE Project: inlets and system elements.

This infrastructure, expected to be fully operational in 2014, has been strongly debated until its beginning, with regard to effectiveness and cost.

The Italian Environmental Association "Italia Nostra" (http://www.italianostra-venezia.org/), for example, drafted 28 reasons against MOSE, that can be summarised as follows:

- damage to the environment (this non-reversible intervention will make definitive the disequilibrium of the natural environment; deepening with excavations the lagoon bottom and other dredging and material handling operations; the strong visual impact of the big gates; the construction of a big artificial island, 35,000 square meters, length 500 m, width 100-200 m, in the middle of the Lido inlet; the disruption of some littoral dunes of high naturalistic value; the duration of the yard works, causing high water roiling with consequences for the marine ecosystem; the water contamination due to the corrosion of the steel gates);
- uneconomic costs not only for the construction, but also for management and maintenance (long-time submerged structures cannot be properly protected against deterioration);
- ineffectiveness (system obsolete in comparison with the forecast of sea rising during this century, +50 cm; useless, because inactive, for tides lower than 110 cm, but also inadequate for exceptional levels, because the 79 gates are not watertight reciprocally: the water can enter the lagoon also with shut barriers; the system counterproductive action with gates closed, in case of strong rainfall and/or river overflowing; the technical risk of the gates out-of-phase resonance, due to wave impacts, until collapse);
- unconformities with the Special Law for Venice (139/1992: lagoon hydraulic re-balancing, big ship traffic removal, fishing valleys opening before any structural intervention), the Special Law 798/1984 (reversibility of any intervention made at the lagoon inlets), the negative judgement of the Commission expressing the Environmental Impact Assessment.

The modifications of the Venice lagoon dynamics (due to the realization of the Lido artificial island) are also cited in Ghezzo et al. (2010): thanks to simulations of realistic tide/wind scenarios, this article affirms that MOSE entails changes to the structure of the lagoon's inlets, with consequences for the areas near the inlets and for the dynamics of the lagoon ecosystem as a whole (the Lido sub-basin tends to increase its extension due the southward movement of the watershed, at the expense of the Chioggia sub-basin, whereas the Malamocco sub-basin changes its relative position, but not its extension); the main conclusion from the article are that the Lido sub-basin can improve its renewal time, but the more intense current speeds can be a risk for the conservation of habitats and infrastructures; finally, the micro-circulation between the breakwater and the coast in Chioggia and Malamocco inlets can be a trap for pollutants or suspended sediment.

Furthermore, in a very recent work of Panza et al. (2014), identifying a potential seismic source located inland very near Venice, it has been evaluated how a tsunami wave can affect the MOSE gates if they are standing up (closed) during the tsunami event. From this simulation, both wave peaks and troughs as first arrivals have been taken into account. Within the paper interesting points of discussion are arising:

- in the peak case, are the MOSE gates able to sustain the pressure of a wave hitting them in the opposite direction, compared to the one of the sea tide?
- in the trough case, considering that the MOSE gates have been designed to stand up also thanks to the Archimedes' principle, what can happen if the water level decreases significantly due to the tsunami?
- the width of the Venice lagoon is about 10 km; it is possible to argue that a tsunami wave, generated by an inland source, can cross the lagoon in less than 15 minutes. In this case, which is the time needed to reopen MOSE gates eventually standing up during the tsunami event?

2.4. Other measures

Banks and public paved areas in the lowest lying zones are being raised to defend the city against the most frequent floods. The ground level of San Marco square has been raised a number of times and will be defended now without additional raising of pavements. There are plans to raise other low-lying areas to defend against tides up to at least + 110 cm (Walraven et al. 2008). Together with complementary measures such as coastal reinforcements, raising quaysides and paving, and improving the lagoon environment, the barriers and the lock will protect the city from extreme events such as floods as well as morphological degradation. Inner canal dredging and hydrodynamic measurements in Venice have also been carried out to address speculations of water flow changes within the canals prompted by relative sea level rise. Previous research on canal hydrodynamics in Venice has provided valuable data on tide levels and water speed and direction (Scully et al. 2011). New devices are utilised for measuring water level, and velocity to address speculations of water flow changes within the canals prompted by relative sea level rise and recent lagoon constructions. Recent developments are also capable of producing highly accurate water level forecasts using sophisticated modelling techniques for the city, however, this information is not specific to the individual canals. Instead, this data is collected from locations within the lagoon and other areas surrounding Venice. Therefore this data cannot be used to predict the hydrodynamic conditions in the inner canals. Other interventions included raising city pavements, dredging inner canals, developing a new fire hydrant network, and fire-proofing public buildings.

3. Early warning systems

3.1. Floods

Non-structural measures against floods (i.e. monitoring, forecasting, information and alerting activities) are carried out by the Tidal Forecasting and Early Warning Centre (ICPSM), instituted in 1980 by the Municipality of Venice. Monitoring is realised through different networks. The ICPSM technical staff elaborates, three times a day, the two days long tide forecast and communicates it to the citizens through different means (website, local newspapers, info points, graphic displays, answering service). In case of flooding tides, alerting services are activated (siren alarm, call manager, alerting SMS, phone calls).

3.2 Earthquakes

A strategy for the mitigation of earthquakes impact on mankind should be oriented to cost-effective preventive measures, aimed at creating knowledge-based hazard resilient public assets, rather than to highly expensive post-disaster rescue and relief operations that currently prevail in many countries. Time-dependent hazard scenarios, by providing basic knowledge of expected earthquake occurrence (location, time, and magnitude) and related ground motion, can be helpful in reorienting the current strategies toward increased earthquake preparedness. Accordingly, in addition to the standard procedure for the neo-deterministic definition of ground shaking maps, an integrated approach to Seismic Hazard Assessment (SHA) has been developed that combines (a) different pattern-recognition algorithms designed for the space–time identification of impending strong earthquakes, with (b) the procedure for the realistic modeling of seismic ground motion A set of neo-deterministic scenarios of expected ground motion, associated with the alarmed areas, is defined by means of full waveform modeling at regional and local scales, thus providing a prioritization tool for timely preparedness and mitigation actions. In the proposed integrated method, the constraint about the space and time of occurrence of impending strong earthquakes is provided by two different intermediate-term middle-range earthquake prediction algorithms, namely CN and M8S algorithms, which are routinely applied for the identification of alerted areas through the real-time monitoring of seismicity in the Italian territory and its surroundings. An intermediate-term middle-range earthquake prediction experiment is ongoing since 2003, aimed at a real-time testing of M8S and CN predictions for earthquakes with magnitude larger than a given threshold (namely 5.4 and 5.6 for CN algorithm, and 5.5 for M8S algorithm) in the Italian region and its surroundings. Predictions are regularly updated every two months and a complete archive of predictions is made available online (http://www.ictp.trieste.it/www_users/sand/prediction/prediction.htm), thus allowing for a rigorous testing of the predictive capability of the applied algorithms. The results obtained during the several years of real-time monitoring already permitted a preliminary assessment of the significance of the issued predictions (Panza et al. 2012 and references therein).

3.3 Tsunamis

The hypothetic kinematic modes about seismic and tsunami early warning systems are developed using the standard methodology of the travel times for seismic S and P waves as well as for the tsunamis travel times (Ranguelov 2014). The models covered all seismic active zones in Italy. The travel times of the P, S, and S-P seismic waves to the city of Venice are calculated. These calculations can be used by the local authorities, decision makers and other responsible institutions (like Civil Defence of Venice) for the development of Standardised Early Warning System (SEWS) increasing the resilience of Venice infrastructure and population in case of strong earthquake occurring anywhere in Italy. The models of the travel times of tsunamis propagating trough the Adriatic Sea and the calculations of them show relatively high effectiveness of the Tsunami Early Warning System (TEWS) regarding Venice lagoon and low surrounding coasts (Ranguelov 2014). Considering the results obtained by the investigations of the kinematic models stated above (both for earthquakes and tsunamis) two possible directions are suggested:

- to use the existing infrastructure of the national seismic network in Italy. This means to use the closest seismic sensors to the respective seismic zone, to trigger the signalling device in Venice. The advantage of such approach do not need special network creation covered the whole Italy;
- another approach is to create the new established system locating in each seismic source specialized devices and connect all of them in a specialized SEWS; this approach creates independent approach to the SEWS use, but a unification of all devices in the SEWS and TEWS is essential.

The creation of a TEWS is necessary due to the possibility of a coincidence in time of the high water level (for example seasonal flood or storm surge, etc.) and the tsunami generation in a far field source. In such a moment the small additional water level increase can generate much more destruction due to the nonlinear effects observed in similar situations (Ranguelov 2011). The TEWS needs a specialized approach for the assessment of the locations and the equipment of it. The previous investigations show that each site needs specific equipment based on the specialized investigations, based on the local conditions. The construction of a specific decision matrix, specialized protocols of announcements and other elements providing the warning issue to the authorities and population is another direction which must be developed for any Early Warning System (EWS).

4. The UNISDR Program "Making Cities Resilient" at Venice

The City of Venice takes part to the UNISDR Program "*Making Cities Resilient: My City is getting ready*". The main results about the implementation of the Hyogo Framework for Action (HFA) under 10 essentials for Making Cities Resilient (2011-2013) are reported in the following Table 2.

5. Conclusions

Historically and over the years a large body of research and evaluation studies have been carried out in relation to Venice. The findings of these studies have influenced policy and strategy but due to climate change and resulting extreme weather conditions, these mitigation efforts need to go further to tackle the challenges that are faced. Many approaches are utilised in different countries to increase overall systemic resilience. These overall categories of approaches can be summarised as below and a variety of these methods are implemented in the City of Venice in different forms at different time periods (Table 3). There is a strong need for all stakeholders to work together collaboratively. Policy makers, academics, professionals and other service providers must share a common platform where all new information and technological innovations can be shared collectively.

Table 2. Monitoring and progress review process of the full local 10 essentials report.

Essential 1	*Put in place organization and coordination to understand and reduce disaster risk, based on participation of citizen groups and civil society. Build local alliances. Ensure that all departments understand their role to disaster risk reduction and preparedness*
Level of Progress achieved: 5	How well are local organizations (including local government) equipped with capacities (knowledge, experience, official mandate) for disaster risk reduction and climate change adaptation?
Level of Progress achieved: 5	To what extent do partnerships exist between communities, private sector and local authorities to reduce risk?
Level of Progress achieved: 3	How much does the local government support vulnerable local communities (particularly women, elderly, infirmed, children) to actively participate in risk reduction decision-making, policy making, planning and implementation processes?
Level of Progress achieved: 4	To what extent does the local government participate in the national DRR planning?

Essential 2	*Assign a budget for disaster risk reduction and provide incentives for homeowners, low-income families, communities, businesses and public sector to invest in reducing the risks they face*
Level of Progress achieved: 3	How far does the local government have access to adequate financial resources to carry out risk reduction activities?
Level of Progress achieved: 4	To what degree does the local government allocate sufficient financial resources to carry out DRR activities, including effective disaster response and recovery?
Level of Progress achieved: 2	What is the scope of financial services (e.g. saving and credit schemes, macro and micro-insurance) available to vulnerable and marginalised households for pre- disaster times?
Level of Progress achieved: 2	To what extent are micro finance, cash aid, soft loans, lone guarantees etc. available to affected households after disasters to restart livelihoods?
Level of Progress achieved: 2	How well established are economic incentives for investing in disaster risk reduction for households and businesses (e.g. reduced insurance premiums for households, tax holidays for businesses)?
Level of Progress achieved: 2	To what extent do local business associations, such as chambers of commerce and similar, support efforts of small enterprises for business continuity during and after disasters?

Essential 3	*Maintain up-to-date data on hazards and vulnerabilities, prepare risk assessments and use these as the basis for urban development plans and decisions. Ensure that this information and the plans for your city's resilience are readily available to the public and fully discussed with them*
Level of Progress achieved: 5	To what degree does the local government conducted thorough disaster risk assessments for key vulnerable development sectors in your local authority?
Level of Progress achieved: 4	To what extent are these risk assessments regularly updated, e.g. annually or on a bi-annual basis?
Level of Progress achieved: 5	How regularly does the local government communicate to the community, information on local hazard trends and risk reduction measures (e.g. using a Risk Communications Plan) including early warnings of likely hazard impact?
Level of Progress achieved: 5	How well are local government risk assessments linked to, and supportive of, risk assessments from neighbouring local authorities and state or provincial government risk management plans?
Level of Progress achieved: 4	How well are disaster risk assessments incorporated into all relevant local development planning on a consistent basis?

Essential 4	*Invest in and maintain critical infrastructure that reduces risk, such as flood drainage, adjusted where needed to cope with climate change*
Level of Progress achieved: 4	How far do land use policies and planning regulations for housing and development infrastructure take current and projected disaster risk (including climate related risks) into account?
Level of Progress achieved: 4	How adequately are critical public facilities and infrastructure located in high risk areas assessed for all hazard risks and safety?
Level of Progress achieved: 4	How adequate are the measures that are being undertaken to protect critical public facilities and infrastructure from damage during disasters?
Essential 5	*Assess the safety of all schools and health facilities and upgrade these as necessary*
Level of Progress achieved: 4	To what extent have local schools, hospitals and health facilities received special attention for "all hazard" risk assessments in your local authority?
Level of Progress achieved: 4	How safe are all main schools, hospitals and health facilities from disasters so that they have the ability to remain operational during emergencies?
Level of Progress achieved: 4	To what degree do local government or other levels of government have special programs in place to regularly assess schools, hospitals and health facilities for maintenance, compliance with building codes, general safety, weather-related risks etc.?
Level of Progress achieved: 4	How far are regular disaster preparedness drills undertaken in schools, hospitals and health facilities?

Essential 6	*Apply and enforce realistic, risk compliant building regulations and land use planning principles. Identify safe land for low-income citizens and develop upgrading of informal settlements, wherever feasible*
Level of Progress achieved: 4	How well are risk-sensitive land use regulations and building codes, health and safety codes enforced across all development zones and building types?
Level of Progress achieved: 4	How strong are existing regulations (e.g. land use plans, building codes etc.) to support disaster risk reduction in your local authority?

Essential 7	*Ensure education programmes & training on disaster risk reduction are in place in schools and communities*
Level of Progress achieved: 5	How regularly does the local government conduct awareness-building or education programs on DDR and disaster preparedness for local communities?
Level of Progress achieved: 3	To what extent does the local government provide training in risk reduction for local officials and community leaders?
Level of Progress achieved: 3	To what degree do local schools and colleges include courses, education or training in disaster risk reduction (including climate related risks) as part of the education curriculum?
Level of Progress achieved: 4	How aware are citizens of evacuation plans or drills for evacuations when necessary?

Essential 8	*Protect ecosystems and natural buffers to mitigate floods, storm surges and other hazards to which your city may be vulnerable. Adapt to climate change by building on good risk reduction practices*
Level of Progress achieved: 4	How well integrated are local government DRR policies, strategies and implementation plans with existing environmental development and natural resource management plans?
Level of Progress achieved: 5	To what degree does the local government support the restoration, protection and sustainable management of ecosystems services?
Level of Progress achieved: 3	How much do civil society organizations and citizens participate in the restoration, protection and sustainable management of ecosystems services?
Level of Progress achieved: 4	How much does the private sector participate in the implementation of environmental and ecosystems management plans in your local authority?

Essential 9	*Install early warning systems and emergency management capacities in your city and hold regular public preparedness drills*
Level of Progress achieved: 3	To what degree do local institutions have access to financial reserves to support effective disaster response and early recovery?
Level of Progress achieved: 4	To what extent are early warning centres established, adequately staffed (or on-call personnel) and well resourced (power back-ups, equipment redundancy etc.) at all times?
Level of Progress achieved: 5	How much do warning systems allow for adequate community participation?
Level of Progress achieved: 4	To what extent does the local government have an emergency operations centre (EOC) and/or an emergency communication system?
Level of Progress achieved: 3	How regularly are training drills and rehearsal carried out with the participation of relevant government, non-governmental, local leaders and volunteers?
Level of Progress achieved: 4	How available are key resources for effective response, such as emergency supplies, emergency shelters, identified evacuation routes and contingency plans at all times?

Essential 10	*After any disaster, ensure that the needs of the survivors are placed at the centre of reconstruction with support for them and their community organizations to design and help implement responses, including rebuilding homes and livelihoods.*
Level of Progress achieved: 5	How much access does the local government have to resources and expertise to assist victims of psycho-social (psychological, emotional) impacts of disasters?
Level of Progress achieved: 4	How well are disaster risk reduction measures integrated into post-disaster recovery and rehabilitation activities (i.e. build back better, livelihoods rehabilitation)?
Level of Progress achieved: 2	To what degree does the Contingency Plan (or similar plan) include an outline strategy for post disaster recovery and reconstruction including needs assessments and livelihoods rehabilitation?

Table 3. Categories of approaches to increase overall systemic resilience.

Category of Approach	**Description of Measures**
Use the landscape to promote safety and livability by preserving and expanding natural protective features for their capacity	• Beach protection • Wetland restoration • Vegetation use and management • River protection
Use construction techniques and technologies to provide an enhanced level of safety for structures and occupants	• Elevation, change in design, inputs, etc., for homes and infrastructure • Use of standards to regulate construction
Use structural defenses (engineered or non-engineered) to resist hazardous impacts by reducing or eliminating exposure to the hazard	• Engineered defenses (e.g., levees, storm surge barriers, sea gates, floodwalls, revetments) • Natural defenses (e.g., barrier islands and reefs, dunes)
Use land use management approaches to reduce exposure to hazards by removing assets and increase resilience through regulatory requirements	• Development rights • Zoning • Development activities (e.g., Greenbelts) • Relocation of assets and infrastructure
Use market-based methods (e.g., taxes, subsidies) as incentives to promote and encourage activities that increase resilience and reduce vulnerability	• Incentives – taxes, fees, subsidies • Buyout of assets or infrastructure in exposed areas • Insurance programs
Use education and outreach to better prepare citizens and businesses on potential risks, emergency responses, community preparedness, etc.	• Education and training • Community preparedness • Emergency-response systems and capabilities • Vulnerable populations
Use methods that increase the overall strength of the community and supporting systems by lowering the extent of damage a single event has and increasing the ability to respond	• Redundancies and backups • Information to enable learning and foresight

Many decisions need to be taken at local level with the engagement of local communities for them to be effective and implemented successfully. The data and results are needed to understand change and design adaptation measures to cope with it, but attention has to be paid to improve data communication. Many constraints can be overcome with integration of climate information into the decision making process, and incorporating impact and risk assessment tools, such as GIS-maps and geospatial indicators. In order to support the use of climate scenarios in urban planning and facilitate decision making processes in uncertain situations, the Decision Support Systems (DSS) are important tools that allow to spatially visualise the potential consequences of climate change in different natural and human systems and sectors. There are many excuses for inaction, one being the communication of uncertainty but it should rather be interpreted as a range of possibilities of what the future might be.

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